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Inter-nesting distribution of green turtles (*Chelonia mydas*) and flatback turtles (*Natator depressus*) at the Lacepede Islands, Western Australia

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Abstract

The inter-nesting distributions of green (*Chelonia mydas*) and flatback (*Natator depressus*) turtles nesting at the Lacepede Islands, off the Kimberley coast of Western Australia, were studied during the 2009–2010 nesting season. Twenty-two satellite transmitters were attached to green and flatback turtles nesting on the West Island rookery; of these, inter-nesting data were received for 10 green and 5 flatback turtles. Turtles were tracked for 20–83 days during inter-nesting. Key findings from this study indicate that flatback turtles generally have a broader inter-nesting distribution than green turtles. All flatback turtles travelled at least 26 km from the nesting beach during inter-nesting, whereas only 2 of the 10 green turtles travelled more than 10 km from the nesting beach. Individuals of both species travelled to within 5 km of the Western Australian mainland coast during inter-nesting. This study has also demonstrated that satellite transmitters can be successfully deployed on green and flatback turtles early in the nesting season without significant data loss due to transmitters being damaged by nesting and inter-nesting behaviours.

Keywords: inter-nesting, green turtles, flatback turtles, satellite telemetry, Lacepede Islands, Kimberley region.

Introduction

Western Australia's nesting populations of green and flatback turtles are thought to be amongst the largest in the world (Limpus 2009). While major rookeries have been identified (see Prince 1994; Limpus 2009), little is known about the inter-nesting movements of flatback and green turtles within Western Australia (Pendoley 2005). With increasing tourism and industrial development along Western Australia's coastline and offshore islands it is important to understand the inter-nesting distributions of Western Australia's marine turtle populations, so that potential impacts to these turtles can be understood and managed (Limpus 2009; Waayers 2010). Understanding differences in inter-nesting behaviours between species sharing the same nesting beaches is also important, to provide rationale for species-specific management decisions.

Satellite telemetry has been used extensively to record the behaviour and distribution of marine turtles, often with a focus on post-nesting migration pathways (Stoneburner 1982; Duron-Dufrenne 1987; Godley *et al.* 2008). Satellite transmitters have generally been deployed on nesting turtles late in the season to reduce the risk of loss/failure during mating, nesting and inter-nesting. As a result, the inter-nesting period is often not captured (Godley *et al.* 2002; Hays *et al.* 2007; Godley *et al.* 2008), although inter-nesting movements have occasionally been recorded inadvertently when turtles have nested after transmitter deployment (*e.g.* Blumenthal *et al.* 2006; Whiting *et al.* 2007).

Unlike post-nesting migratory pathways, which can cover several hundreds and even thousands of kilometres (*e.g.* Cheng 2000; Blumenthal *et al.* 2006), inter-nesting areas are much more localised (Pendoley 2005). Determining the extent of inter-nesting areas via satellite telemetry therefore requires the ability to distinguish fine-scale movements.

While the Argos satellite system has revolutionised the ability to track animal movements, location accuracies are highly variable. The highest accuracy Argos locations (Location Classes 3, 2 and 1) vary in accuracy from 250–1500 m (Argos CLS 2008), with some field tests indicating even lower accuracies (Hazel 2009). Such low accuracies are considered by the researchers to be insufficient for tracking the fine-scale inter-nesting movements of marine turtles.

Advances in satellite telemetry have led to the development of Fastloc GPS technology, which allows the acquisition of GPS locations within a very short timeframe. The accuracy of Fastloc GPS locations varies with the number of satellites used to acquire the location. Field tests by the manufacturer indicate that 95% of locations acquired with more than 10 satellites are accurate to 17 m but that effective locations (95% of locations accurate to within 140 m) can be acquired with as few as 5 satellites (Bryant 2007).

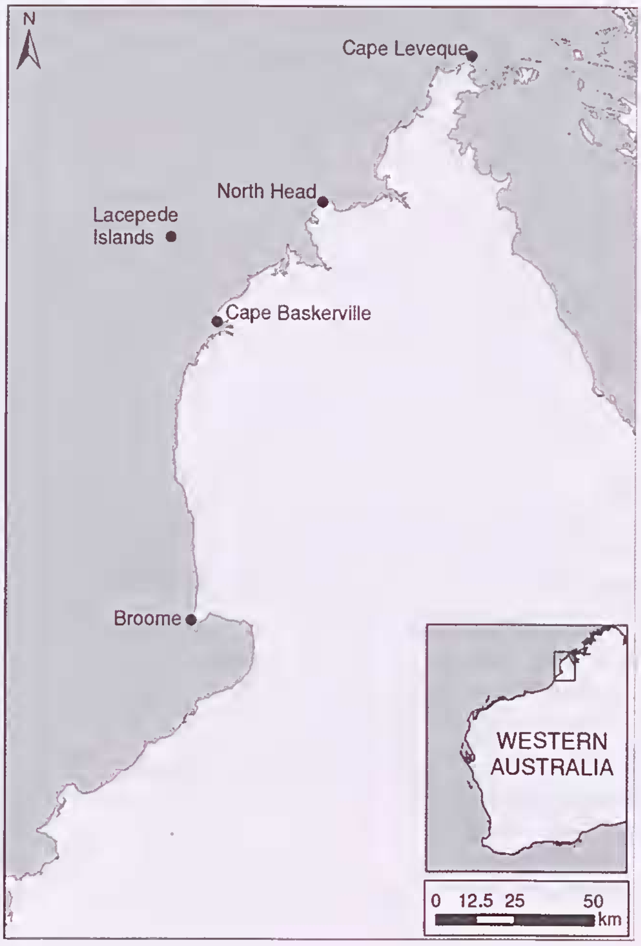

Figure 1. Study area.

While Fastloc GPS locations are generally more accurate than Argos locations, they require more battery power to obtain (Hazel 2009). When programming satellite transmitters it is therefore necessary to achieve a compromise between the number of attempted GPS location acquisitions and the duration that the transmitter will continue to operate.

The Lacepede Islands, approximately 110 km north of Broome in the Kimberley region of Western Australian (Fig. 1), support one of Western Australia's largest green turtle rookeries and lesser numbers of nesting flatback turtles (Prince 1994; Limpus 2009). Despite the importance of the Lacepede Islands for marine turtle nesting, limited data have been published for the area. The objective of this research was to determine the spatial distributions of inter-nesting green and flatback turtles at the Lacepede Islands. A secondary objective was to determine whether satellite transmitters deployed early in the nesting season would continue to provide data throughout the inter-nesting period or would malfunction partway through the inter-nesting period.

Methods

Transmitter attachment

Twenty F4G-291A (Sirtrack Pty Ltd, New Zealand) and two Mk10-AF (Wildlife Computers Inc.) satellite transmitters were attached to nesting green and flatback turtles at the Lacepede Islands during the 2009–2010 nesting season. All satellite transmitters were deployed from West Island (16°51' S; 122°7' E), the western island of the Lacepede Islands, between 7pm and 2am in December 2009 and February 2010.

Twelve F4G-291A transmitters were attached to 6 green turtles and 6 flatback turtles between 2 and 4 December 2009. The remaining 8 F4G-291A transmitters were attached to 4 green and 4 flatback turtles between 9 and 10 February 2010. The 2 Mk10-AF transmitters were attached to 1 green turtle and 1 flatback turtle on 9 February 2010.

Transmitters were attached to green turtle carapaces according to the methods described by Balazs *et al.* (1996). Green turtles were directed into a large pen (2x2 m) made of plywood for transmitter attachment. Transmitters were attached onto the second central scute using 2-part epoxy resin (Powerfast Pro™) and then coated with antifouling paint (International Longlife). Due to the high humidity, the glue and antifouling paint took about 3.5 hours to dry.

Transmitters were attached to flatback turtles using harnesses as described by Sperling and Guinea (2004). Each harness comprised a moulded polypropylene base-plate, 22 mm wide webbing with Velcro ends and a centralised plastron ring with raised nodules to reduce the potential for snagging (Crackpots Marine and Rural Supplies, Perth). Satellite transmitters were fixed to the base-plate using a fast-curing marine adhesive/sealant and stainless steel screws and coated with antifouling paint (International Longlife) prior to attachment.

Transmitter Settings

Both the F4G-291A and Mk10-AF transmitters provide Argos and Fastloc GPS location data. The Mk10-AF transmitters also provide time-depth data but these data are not presented here.

Transmitter duty cycles were selected to provide a balance between Argos and GPS data. The F4G-291A transmitters were programmed to be switched on continuously for the first 90 days, after which the duty cycle switched to 12 hours on then 72 hours off. GPS location acquisition was attempted every hour and Argos location acquisition was attempted every 40 seconds when the tags were switched on. The Mk10-AF transmitters were programmed to be switched on continuously during February (deployment month) and every third day during all other months. GPS location acquisition was attempted every 20 minutes and Argos location acquisition was attempted every 45 seconds when the tags were switched on.

Data filtering

Location and time data were obtained from the Argos satellite system (http://www.argos-inc.com). Although both Argos and GPS data were collected, only GPS data were included in the analyses. GPS data for the F4G-291A and Mk10-AF transmitters were processed with Sirtrack Fastloc Admin Tool Version 1.1.5.8 (Sirtrack Pty Ltd) transmitters and Wildlife Computers Data Analysis Program Version 2.0 (Wildlife Computers Inc.), respectively. Data were filtered to include only those locations obtained from five or more satellites. One location (for turtle G6) was also removed as it would have required the turtle to swim >5km/h (Luschi *et al.* 1998).

The end of inter-nesting for each turtle was determined from their last potential nesting event for the season, which was defined as a location within 140 m of a sandy beach followed by a period of >30 days without being recorded within 140 m of a sandy beach. The distance of 140 m was based on 95% of locations obtained with 5 satellites being within 140 m of the actual location (Bryant 2007). Although this may have lead to some locations acquired with more than 5 satellites being mistakenly identified as potential nesting events, it was assumed that turtles would commence their post-nesting migrations and leave the inter-nesting area relatively quickly after completing their nesting season (Dodd and Byles 2003; Kennett *et al.* 2004).

Data analyses

Inter-nesting data were plotted in ArcGIS to show the inter-nesting distribution for green and flatback turtles and to calculate the maximum distance each turtle travelled from the site of transmitter attachment. Density histograms with a kernel density estimation of the probability density function of transmissions were generated for both green and flatback turtles, to show the density of transmissions within distance categories from the deployment location. Boxplots were also prepared to examine the variation in distance from the deployment location for green and flatback turtles. Locations that were greater than 1.5 x the inter-quartile range were plotted as outliers.

Study limitations and assumptions

Location data are only acquired when the transmitter aerials break the sea surface. The distribution data therefore only represent the locations of turtles at the sea surface. Substantially more transmissions per day were received for green turtles than for flatback turtles. As this was a consistent pattern throughout all tracked turtles, it may be attributable to behavioural differences between green and flatback turtles. (*e.g.* green turtles spend more time at the sea surface than flatback turtles).

It is not known whether the turtles tracked in this study had nested in the weeks or months prior to transmitter attachment, therefore the distribution data may cover only a portion of the inter-nesting period. We have assumed that turtle inter-nesting movements are uniform throughout the inter-nesting period.

Results

Transmitter success and numbers or transmissions received

Of the 22 turtles tagged with satellite transmitters, inter-nesting data were received for 10 green and 5 flatback turtles (Table 1). For 3 of the remaining 7 turtles the GPS function of the transmitters failed, while 1 green and 3 flatback turtles commenced their post-nesting migration immediately after the transmitter was attached.

Green and flatback turtles remained in the inter-nesting area for 20–83 days and 21–40 days after transmitter attachment, respectively (Table 1). All green turtles had left their inter-nesting area and commenced their post-nesting migration by 4/05/2010, indicating that the green turtle nesting at the Lacepede Island occurs from at least December–May, whereas all flatback turtles commenced their post-nesting migration by 12/01/2010 indicating possibly a much shorter nesting season (Table 1). Numbers of transmissions used in the analyses (after data filtering) ranged from 45–599 for green turtles and from 12–142 for flatback turtles. The mean number of transmissions received each day ranged from 1.07–7.22 for green turtles and 0.30–4.18 for flatback turtles (Table 1).

Table 1

Summary of inter-nesting data from satellite transmitters attached to green and flatback turtles nesting at the Lacepede Islands (G=Green turtle; F=Flatback turtle).

Turtle ID	Transmitter model	Release date	Date of last potential nesting event	Days in inter-nesting area area after release	Number of data points used in analyses	Mean no. of locations received each day	Maximum distance travelled from nesting beach (km)
G1	F4G-291A	2/12/2009	13/01/2010	42	45	1.07	1.69
G2	F4G-291A	2/12/2009	18/01/2010	47	266	5.66	7.25
G3	F4G-291A	3/12/2009	11/01/2010	39	182	4.67	3.35
G4	F4G-291A	3/12/2009	8/01/2010	36	162	4.50	8.14
G5	F4G-291A	4/12/2009	5/02/2010	63	273	4.33	9.45
G6	F4G-291A	4/12/2009	16/02/2010	74	383	5.18	9.29
G7	Mk10-AF	9/02/2010	1/03/2010	20	114	5.70	7.16
G8	F4G-291A	9/02/2010	15/03/2010	34	219	6.44	24.29
G9	F4G-291A	10/02/2010	14/03/2010	32	115	3.59	9.81
G10	F4G-291A	10/02/2010	4/05/2010	83	599	7.22	47.45
F2	F4G-291A	2/12/2009	5/01/2010	34	142	4.18	40.32
F3	F4G-291A	3/12/2009	12/01/2010	40	12	0.30	26.13
F4	F4G-291A	4/12/2009	2/01/2010	29	117	4.03	43.40
F5	F4G-291A	4/12/2009	25/12/2009	21	80	3.81	48.28
F6	F4G-291A	4/12/2009	5/01/2010	32	104	3.25	37.34

Spatial distribution and extent of inter-nesting habitat

Flatback turtles showed a broader spatial distribution than green turtles during inter-nesting, particularly to the north-east and south-west of the Lacepede Islands (Fig. 2). All five flatback turtles travelled at least 26 km from the nesting beach, whereas only 2 green turtles travelled further than 10 km from the nesting beach during inter-nesting (Table 1). Both species travelled to within 5 km of the mainland of Western Australia, although more transmissions were received near the mainland for flatback turtles than for green turtles (Fig. 2).

The distribution data were positively skewed for both green and flatback turtles (Fig. 3). For green turtles the median distribution from the deployment location was 1.84 km (Fig. 3). Excluding outliers, all green turtle transmissions were within 7.65 km of the deployment location (Fig. 3). The median distribution from the deployment location for flatback turtles was 12.51 km, with all transmissions within 48.28 km of the deployment location (Fig. 3).

The majority of transmissions for green turtles were within 10 km of the deployment location with the highest density of transmissions recorded within 1 km of the deployment location (Fig. 4). Transmissions for flatback turtles were much more broadly distributed (Fig. 4). The highest proportions of flatback turtle transmissions were within 0–4 km of the deployment location with the remaining transmissions relatively evenly distributed out to 48 km from deployment location (Fig. 4).

Discussion

Green and flatback turtle inter-nesting distributions

Prior to this study there were no peer-reviewed studies on the inter-nesting distributions of flatback turtles in Western Australia and only limited studies on inter-nesting distributions of green turtles in Western Australia (*i.e.* Pendoley 2005). Satellite tracking studies based on Argos location data indicate that green turtles from Barrow Island (n = 8) and Sandy Island (n = 3) in Western Australia remain within approximately 7 km of their nesting beach during the inter-nesting period (Pendoley 2005). Similarly, the present study found that green turtles generally remained within 10 km but that some turtles occasionally travelled up to 47 km from their nesting beach.

Non peer-reviewed satellite tracking studies using Fastloc GPS location data have shown that inter-nesting flatback turtles from Ashburton Island (n = 6) and Barrow Island (n = 6) in Western Australia travel up to 35 km and 70 km from their nesting beach, respectively. Flatback turtles from both islands travelled to the coastal waters adjacent to the Western Australian mainland between nesting events (Chevron Australia 2009; RPS 2010). Similarly, Sperling (2007) demonstrated that flatback turtles from Curtis Island in Queensland (n = 3) and Bare Sand Island in the Northern Territory (n = 4) travelled up to 30 km from their respective nesting beaches during inter-nesting, using Argos location data.

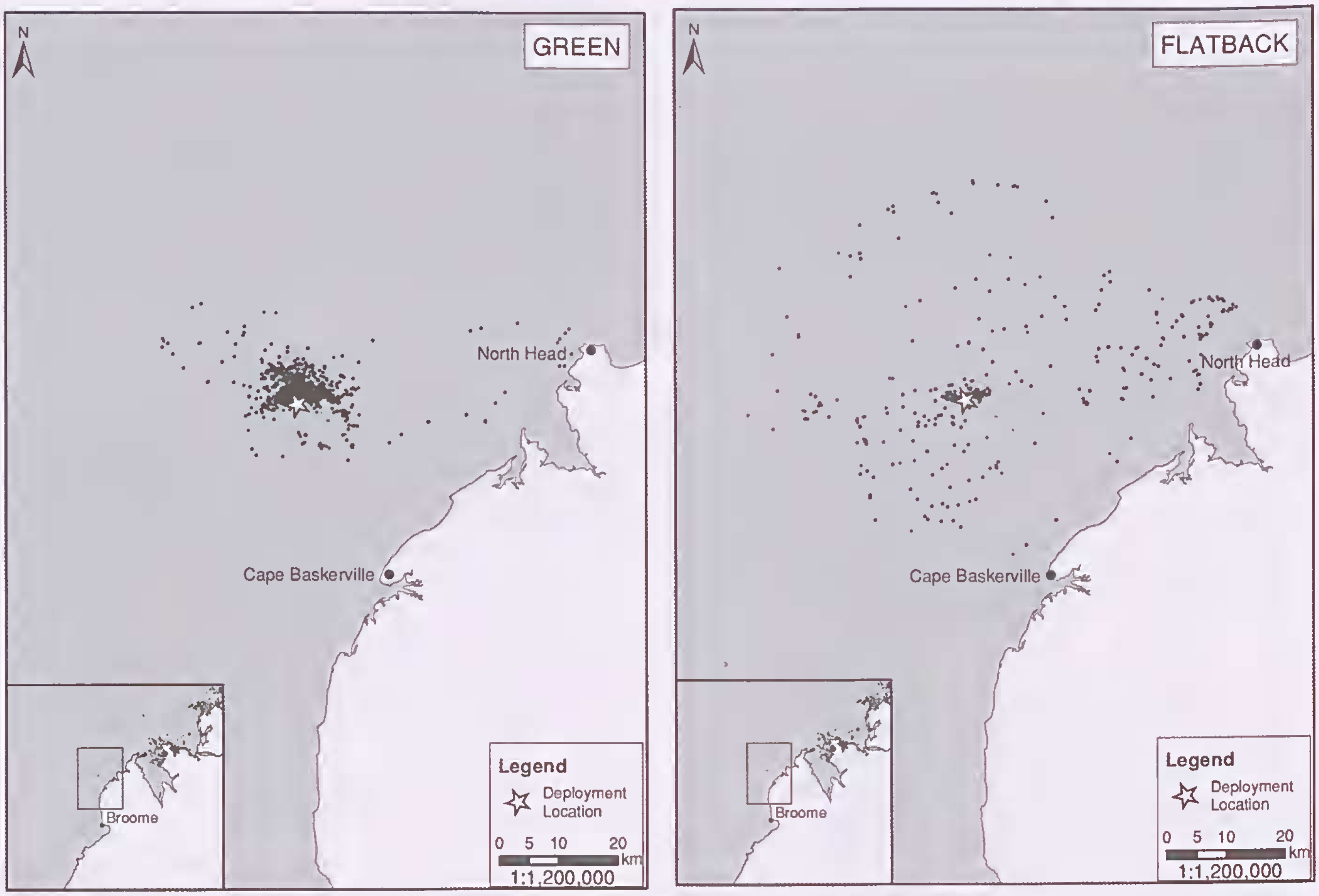

Figure 2. Spatial distribution of GPS (≥5 satellites) locations for green and flatback turtles.

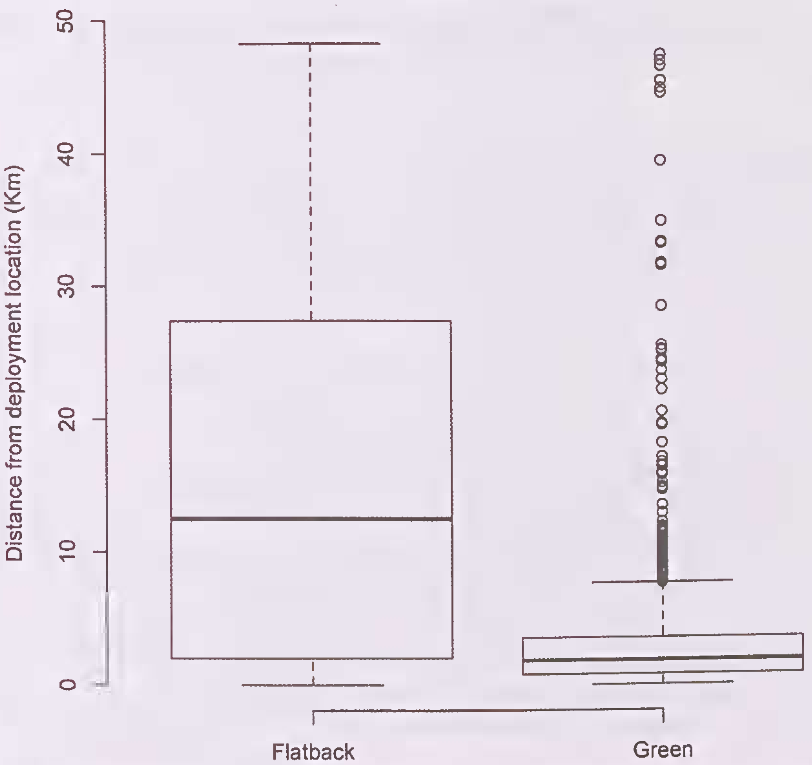

Figure 3. Boxplot of distances from the deployment location for green (n=2358 transmissions) and flatback turtles (n=455 transmission) during the inter-nesting period. Bottom whisker represents 0-25% of data; box represents 25-75% of data; dark line represents median; top whisker represents 75-100% of data; outliers (*i.e.* transmissions outside 1.5 x the inter-quartile range) are represented by circles.

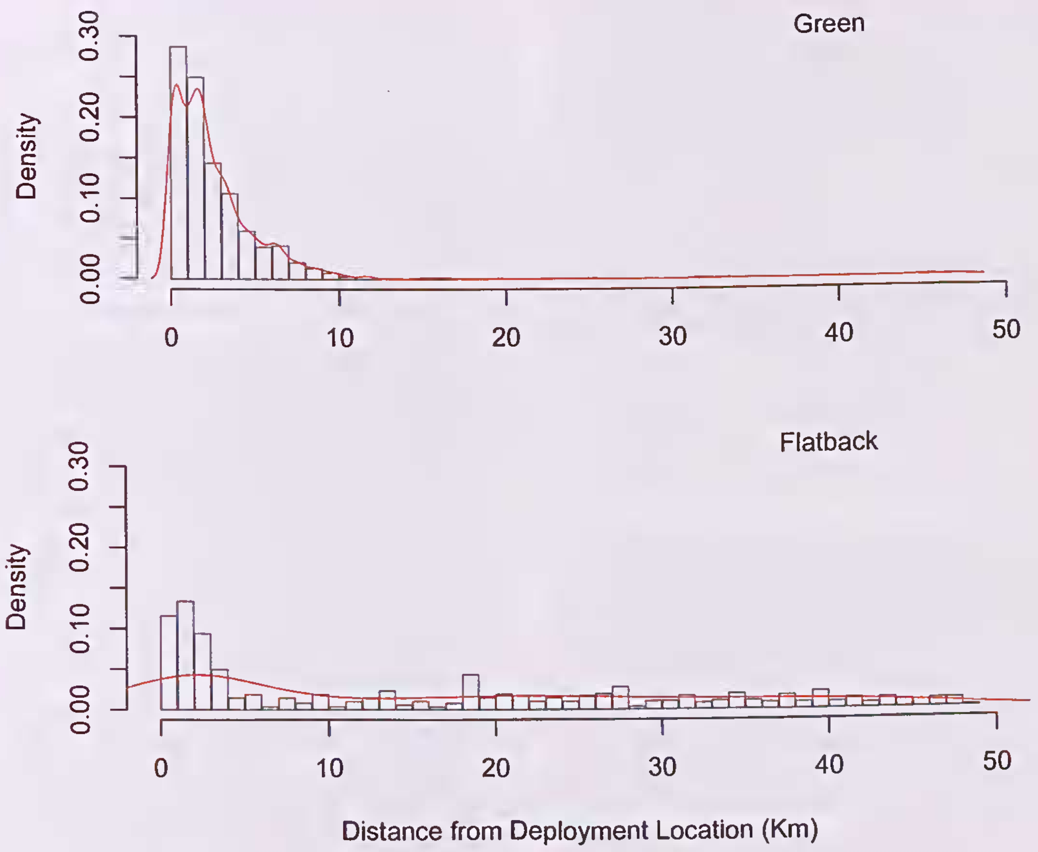

Figure 4. Density histogram (bars) with a kernel density estimation of the probability density function (line) of transmissions at various distances from the deployment location for green (n=2358 transmissions) and flatback turtles (n=455 transmissions) during the inter-nesting period.

Flatback turtles in the present study travelled at least 26 km and up to 48 km from their nesting beach during inter-nesting, which is consistent with the aforementioned studies.

Although only a very small proportion of Western Australia's inter-nesting green and flatback turtles have been tracked using satellite telemetry, there appears to be a general trend for green turtles to remain within 10 km of their nesting beach and for flatback turtles to travel at least 26 km from their nesting beach during inter-nesting.

Deployment of transmitters early in the nesting season

This study has shown that transmitters can successfully be deployed on nesting turtles early in the nesting season without significant data loss from damaged transmitters that fail to operate. Inter-nesting data were received for 15 of the 22 deployed transmitters and post-nesting migration data were received for 19 of the 22 turtles. Three of the 22 tags failed to provide any Fastloc GPS data and it is possible that the GPS aerials for these transmitters were damaged as a result of mating, nesting or inter-nesting behaviours. However, all three of these transmitters continued to provide Argos location data (not presented here), which is suitable for tracking the post-nesting migratory movements of marine turtles (Hays *et al.* 1999).

Further research avenues

Fastloc GPS technology allows for monitoring of the fine-scale movements of turtles during the inter-nesting period. While data analyses for this study were limited to spatial distribution, further analysis of the numbers of haul-out events (*i.e.* nesting events and false crawls) and re-nesting intervals could be undertaken. Time-series modelling of the turtles' movements may also provide a better understanding of patterns in behaviour during the inter-nesting period.

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